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The Feasibility Study of Cotton Pulp Wastewater Treatment with IC Anaerobic Reactor

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Abstract

IC anaerobic reactor can deal with the diluted cotton pulp wastewater with SCOD concentration of 3500mg/l well, the removal rate could reach 68% at the volume load of 18kgcod/m3.d; With regard to the raw cotton pulp wastewater with SCOD concentration 6600mg/l, the removal rate could reach 60% at the volume load of 16kgcod/m3.d, better than the existing pretreatment process with the removal rate of 40%-50%.

Keywords: IC anaerobic reactor, cotton pulp wastewater, granular sludge, volatile fatty acids, volume load

1. Introduction

As the main raw materials of the production of viscose fiber in chemical fiber industry, cotton pulp with linters and caustic soda, hydrochloric acid, sodium hypochlorite, and other chemical raw materials as main raw production materials, is produced through many working procedures, such as cooking, beating, place sand, bleaching and copy choose and so on. The production process of cotton pulp discharges three types of wastewater: thick black liquor, thin black liquid and middle wastewater. The key technology of cotton pulp production wastewater treatment lies in the management of the black washing materials liquor under the ball. On the one hand, the thin black liquor belongs to high concentration organic wastewater, on the other hand, it still contains a lot of organisms that are difficult to biodegrade, such as lignin and macromolecules carbohydrates and so on.

As a new type of anaerobic reactor , IC anaerobic reactor on the basis of the second generation anaerobic reactor——UASB, belongs to an outstanding representative in the third generation of anaerobic reactors, which was first developed successfully and put into practice by PAQUES company from the Netherlands. With many merits such as high volume load, large ratio of height and diameter, land saving, energy efficiency, high processing efficiency and so on, IC anaerobic reactor at present is being mainly

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used in some limited high concentration organic wastewater treatment such as papermaking wastewater and citric acid wastewater. For the anaerobic treatment of the high concentration of cotton pulp wastewater, it is still under investigation in domestic, and hasn't been formed a whole process. This experiment with IC anaerobic reactor as the key equipment is aimed at the feasibility analysis of the cotton pulp wastewater anaerobic treatment through several pilot tests with middle scale experiment equipment.

2. Materials and methods

2.1 Experimental equipment

Experimental device was shown in Fig. 1. IC anaerobic reactor with specifications for diameter 3m, high 14.5 m, effective volume 100m3, could be divided into five areas from top to bottom: the mixed area, 1th anaerobic area, 2nd anaerobic area, precipitation area and gas-liquid separation area. This device was also equipped with a homogeneous adjusting tank with specifications of Φ5×3m3, and a circulation sedimentation tank with specifications of Φ5×3m3. Experimental wastewater that was accommodated to certain standards in the homogeneous adjusting tank mixed with IC effluent from the circulation sedimentation tank, then was together pumped into the rotating distributor at the bottom of the reactor. The inflow was mixed with anaerobic granular sludge in the mixed area, then generated much biogas under the function of biochemical reaction which was collected at the bottom of gas-collecting channel. When the gas reached a certain pressure, the liquid phase below could be raised by air-lifting effect into the gas-liquid separator on the top of the reactor through the inner rising pipe, where gas and liquid could realize separation. After separation, liquid dropped into the mixed area at the bottom of the reactor where a good mixture and stirring could come true.

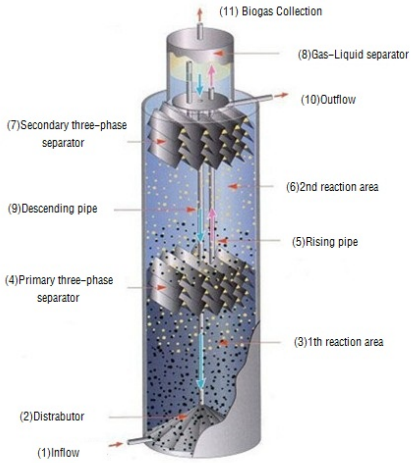

Fig. 1 IC Anaerobic Reactor

2.2 Experimental Wastewater Quality

The experimental wastewater was derived from a sewage draining exit of a pulp production line located in Weifang, Shandong province. The primary pollutants of such wastewater were organic acids, which took up 35.19% of the totals of organics, then were lipoids and ketones, which separately took up 30.03% and

19.68% of the totals of organics. Besides, DPA and phenol as the priority pollutants in environmental control were also detected in the cotton pulp wastewater, which separately took up 7.85% and 5.42% of the totals of organics. This types of wastewater had high chromaticity and alkalinity, and contained high concentration of organic matters that was difficult to be biodegraded. The parameters of the wastewater quality were shown in Table 1.

Table 1 Experimental Original Wastewater Quality

Wastewater Sample	TCOD (mg/L)	SCOD (mg/L)	SS (mg/L)	PH	Chroma (tines)	Temperature (℃)
Thin black liquid	8500-12000	6500-7000	2000-2500	11-13	6000-8000	38-42
Intermediate Wastewater	800-1000	~	~	2~3	100~150	30-40

2.3 Sludge Inoculation

The granular sludge for inoculation was fetched from an IC anaerobic reactor of one food mill in Rizhao, Shandong province. The concentration of sludge for Inoculation was 12 mg/L, the total amount of which was 40m3. Besides, VSS/T SS=0.85.

2.4 Experimental Methods

This article pointed out the regulation and control of the parameters such as the start volume load for reactor and retention time by the control of the inflow concentration, circulating mass and the rate of inflow.

Phase one: This phase domesticated and fostered the granular sludge by pumping into the diluted pulp wastewater with the average TCOD concentration of 5800mg/L and the average SCOD concentration of 3500mg/L. To make sure that the volume load of IC reactor could keep the following levels: 5kgCOD/m3.d,8kgCOD/m3.d,12kgCOD/m3.d,15kgCOD/m3.d, 18kgCOD/m3.d, 20kgCOD/m3.d by controlling the inflow and circulating volume. According to the operational stability of each stage, the debugging process was determined whether to carry out the next step or not. The data of each operational process needed to be recorded for analysis.

Phase two: On the basis of the domesticated granular sludge in Phase one, this phase pumped into the original cotton pulp wastewater by control of the rate of inflow and circulation to make sure that the volume load of reactor could keep the levels below: 8kgCOD/m3.d, 10kgCOD/m3.d, 13kgCOD/m3.d, 16kgCOD/m3.d, 18kgCOD/m3.d, 16kgCOD/m3.d. In addition, in order to ensure that anaerobic bacteria could live in a suitable PH environment, this phase used intermediate wastewater with PH below 3 to adjust PH of inflow to the scope between 7.2 and 7.5. The data of each operational process needed to be recorded for analysis.

2.5 Analysis Methods

（1）CODcr：Dichromate Titration Methods；
（2）SS：Gravimtric Methods；
（3）Sulfate Anion and Sulfite Anion: Gravimtric Analysis Methods；
（4）PH：PH test papers and PH admeasuring apparatus;
（5）Gas Components Analysis ：Orsatgasanalyzer ；
（6）Chroma：Diluted Multiples Methods；

3. Results and analysis

3.1 The Operational Situation of IC Anaerobic Reactor in Different Volume Load in Phase One

In Phase one with diluted pulp wastewater as experimental inflow, the removal rates of SCOD and SS and the situation of VFA in different operational conditions of volume loads were separately shown in Fig 2 and Fig 3. According to Fig 2 and analysis, the treatment effect of IC reactor for the types of wastewater could achieve the best at the volume load of 18kgCOD/m3.d. On the one hand, the removal rate of SCOD reached 68% being the highest rate, on the other hand, according to Fig 3, the VFA as the most direct data that can reflect the operational situation of IC reactor fell down to the lowest rate of 400mg/L. The conclusion that the hydraulic conditions of IC reactor (such as the circulation rate of inflow, hydraulic mixture of inflow, dilution and buffering of inner circulation and retention time, etc.) and the physiological conditions of anaerobic microorganism (such as temperature, PH buffering, the VFA content of effluent and the stimulation of toxic matters like hydrogen sulfide, etc.) achieved the best can be arrived at. Because of the unstable quality and quantity of inflow on the start stage, the data at beginning was only for reference. But reflected from Fig 2, the SS removal rate of IC reactor had been falling down straightly. Through analysis, it was not difficult to arrive at the conclusion below: because of coming from the collecting tank which collected liquid supernatant from sludge concentration tanks and the backflow from sludge dewatering machine rooms, the experimental diluted water contained a lot of aerobic activated sludge flocculent, then was mixed with inflow and pumped into the reactor. The sludge flocculent not only can't be biodegraded, but also the aerobic microorganism in it could compete for organic matters with anaerobic microorganism, then badly influenced anaerobic reaction. With the stimulation of the aerobic sludge and more and more SS in outflow from the top discharge outlet, it became inevitable that the SS removal rate of IC reactor becoming lower and lower.

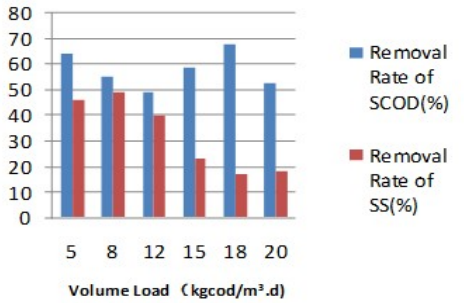

Fig. 2 the Removal Rates of SCOD and SS

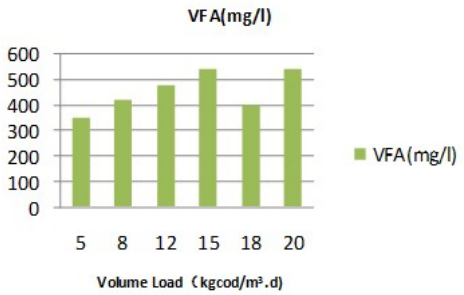

Fig. 3 the Concentration of VFA in Outflow

3.2 The Operational Situation of IC Anaerobic Reactor in Different Volume Load in Phase Two

In Phase two with original cotton pulp wastewater as experimental inflow, the removal rates of SCOD and SS and the situation of VFA in different operational conditions of volume loads were separately shown in Fig 4 and Fig 5. According to Fig 4 and Fig 5 and the analysis for the results, the treatment effect of IC reactor for the types of wastewater could achieve the best at the volume load of 16kgCOD/m3.d. At this volume load, on the one hand, the removal rate of SCOD reached 60% being the highest rate, on the other hand, according to Fig 5, the VFA concentration as the most direct data that can reflect the operational situation of IC reactor fell down to the lowest rate of 400mg/L. When the volume load was raised to 18kgCOD/m3.d, the SCOD removal rate became lower than that at 16kgCOD/m3.d. Besides, the concentration of VFA in outflow increased. But when the volume load was returned back to 16kgCOD/m3.d, the SCOD removal rate returned back to the original level, so did the VFA concentration of outflow. On the one hand, it illustrated that IC anaerobic reactor had a certain ability against the higher impact load, on the other hand, the running effect of IC reactor achieved the best at the volume rate of 16kgCOD/m3.d. That conclusion could be received through the amount of gas production per unit mass of COD, internal circulation situation and the morphology, burnish, particle size distribution of anaerobic granular sludge. Because in this phase the inflow wasn't diluted by backwater and wasn't influenced by aerobic activated sludge floccules, the results can truly reflect the SS removal rate of IC anaerobic reactor. The average removal rate was about 30%.

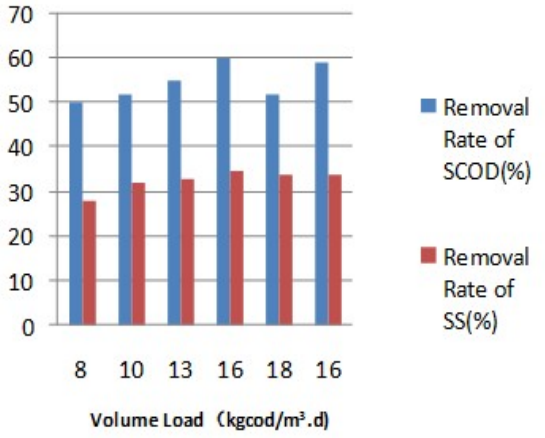

Fig. 4 the Removal Rates of SCOD and SS

The main effect factor of this phase was the PH adjustment. The optimum scope of PH for most of anaerobic microorganisms was between 6.5 and 7.8. But the PH of the raw pulp wastewater reached 11-13. In order to create a neutral environment for anaerobic microorganisms, it was necessary to adjust the PH of inflow with acids. But the intermediate wastewater used to adjust the PH contained higher concentration of sulfate anion and sulfite anion, which was brought into the IC reactor. On the anaerobic condition, SRB would reduce the sulfur of positive sexivalence into negative bivalence, most of which existed in the form of hydrogen sulfide in the reaction area. On the one hand, SRB could compete for organic matters like VFA with MPB, on the other hand, they could produce high toxic matters like hydrogen sulfide which would generate much more toxicity to influence the activity of MPB and the methanogenesis efficiency. In the reaction area, the buffer pairs of HCO3-/H2CO3 and HS-/H2S played a role in buffer action for PH. The increase of the content of sulfate anion and sulfite anion in inflow would

certainly generate more hydrogen sulfide. On the one hand, the hydrogen sulfide would make a bad influence on the growth of MPB, on the other hand, it can create a more suitable environment for anaerobic reaction through enhancing the buffer ability of PH in the reaction area. The contradiction appeared. But the internal circulation of IC reactor effectively resolved this contradiction. The stimulation of the hydrogen sulfide was bound to cause irreversible toxic effect for MPB, but most of the hydrogen sulfide would be separated from liquid phase in gas-liquid separator on the top, which made the concentration of hydrogen sulfide in reaction area keep in a low level. So IC anaerobic reactor can remove parts of sulfate to a certain extent.

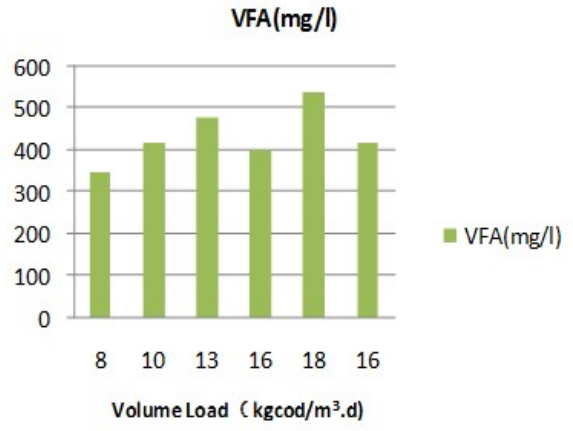

Fig. 5 the Concentration of VFA in Outflow

4. Experimental Conclusions

Although IC anaerobic reactor had a high SCOD removal rate for the cotton pulp wastewater diluted by backwater (mixed with aerobic sludge), this types of wastewater contained high concentration of SS that not only can't be biodegraded by anaerobic bacteria, but also stimulated gradually in reactor. If this situation continued, the disadvantageous effect on the anaerobic granular sludge would occur. So this types of cotton pulp wastewater wasn't suitable for anaerobic treatment with IC reactor.

IC anaerobic reactor could deal with the raw cotton pulp wastewater with SCOD concentration 6600mg/l well. The optimum designing volume load was 16kgcod/m3.d.The TCOD removal rate could reach 50% at the volume load, the SCOD removal rate could reach 55%, better than the existing pretreatment process with the removal rate of 40%-50%. And the processing cost of IC anaerobic reactor was only between 0.8 and 1 yuan, which was far below the existing pretreatment processing between 6 and 8 yuan. IC anaerobic reactor can also generate lots of biogas that can be used as energy, then reduce the cost further. In conclusion, IC anaerobic reactor used for treatment of original cotton pulp wastewater instead of the existing pretreatment process had economic and technical feasibility.

The maximum influencing factor for the treatment of cotton pulp wastewater with IC anaerobic reactor was the high concentration of sulfate in inflow. How much the specific influence extent was, a further research still needed to explore.

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